Technical Data Sheet: Stubborn Balance Zero v1.0

Ultra-Durable Maintenance-Free Hybrid Supercapacitor UPS HAT for Raspberry Pi Zero

Official Product Page: https://www.aqex.eu/stubborn-balance-zero-raspberry-pi-zero-ups-hat-hybrid-supercap.html

1. Product Concept & Strategic Advantages

The **Stubborn Balance Zero** is a specialized uninterruptible power supply designed for the **Raspberry Pi Zero** family. Unlike traditional battery-based systems, it utilizes **Hybrid Supercapacitor (HSC)** technology to provide a maintenance-free, high-endurance power backup solution for industrial and remote IoT applications.

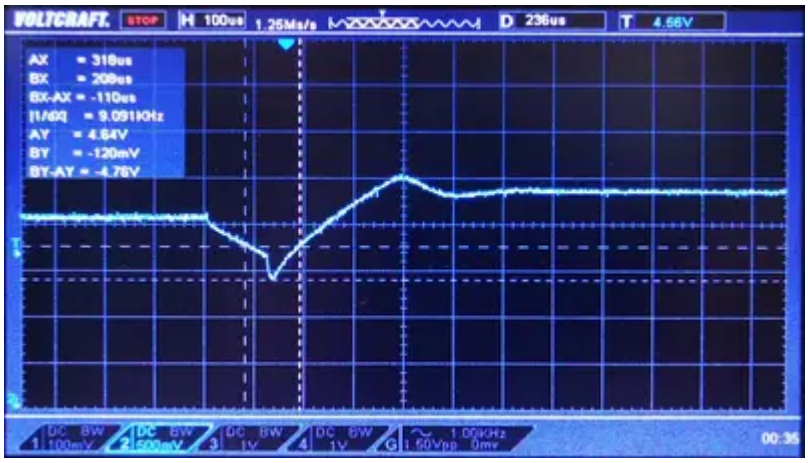
Strategic advantages:

- **Extended Runtime:** Offers significantly higher energy density and longer backup power duration compared to standard supercapacitors.
- **Extreme Longevity:** The HSC technology supports up to 50,000 charge cycles, outlasting traditional Li-ion batteries.
- **Maintenance-Free:** No chemical aging typical of batteries; ideal for hard-to-reach deployments.
- **Superior Temperature Stability:** Operates reliably in environments where standard batteries would fail.
- **Compact Form Factor:** Designed specifically to match the Raspberry Pi Zero's footprint.
- **Zero Maintenance:** No periodic battery replacements required during the typical lifecycle of the equipment.

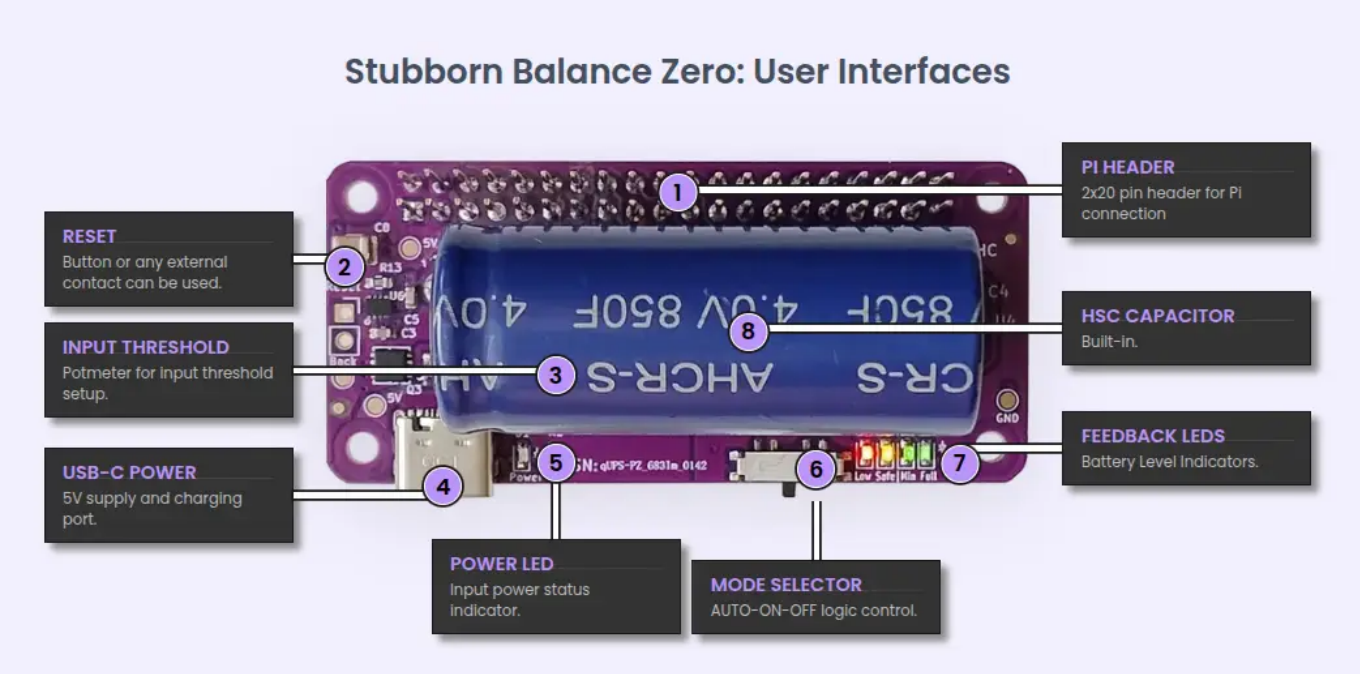
2. Comprehensive Technical Specifications

Parameter	Value	Condition / Detailed Notes
Input Voltage (USB-C)	5.0V – 5.2V	Minimum 2A - 3A recommended
Output Voltage	5.0V DC	Regulated for Raspberry Pi Zero
Storage Technology	Hybrid Supercapacitor	High energy density with long cycle life
Max Continuous Load	**3.5A**	Enhanced current delivery for RPi 5 + Peripherals
Cycle Life	~50,000 Cycles	Industrial grade durability
GPIO Interface	40-pin Header	Pass-through design for stacking
Switchover Time	100 – 300 µs	No-reboot guaranteed transition

> **Design Note:** The **Offline topology** ensures almost zero power loss and heat generation during standard operation. A momentary (<1ms) voltage transient occurs during power failure; however, the Raspberry Pi's internal regulation easily filters this, ensuring zero system instability or reboot.



3. qUPS-P-SC User Interfaces and Indicators



4. Power Management & Protection

Feature	Specification
Logic Control	Hardware-level voltage monitoring
Safety	Protected against over-discharge and input voltage fluctuations
Input Tuning	Potentiometer for input threshold calibration
Restart Logic	Automatic recovery after power restoration in AUTO mode

5. User Interfaces & Configuration

5.1 Mode Selection (Switch 4)

- **OFF:** Complete power cut.
- **ON:** Immediate power-up when power (internal or external) is available.
- **AUTO:** Intelligent start-up logic; only boots the Pi when the battery reaches the "Min" energy level.

5.2 GPIO Communication

The system utilizes a 3-pin GPIO interface for OS-level integration. The following pins are used on the 40-pin Raspberry Pi header:

- **PFO (Power Fail): GPIO 17 (Pin 11)** — Signals external power loss (HIGH = OK / LOW = Backup Mode).
- **LIM (Limit): GPIO 27 (Pin 13)** — Signals that the battery has reached the critical low threshold.
- **SHD (Shutdown): GPIO 22 (Pin 15)** — Handshake signal. The UPS cuts power after the OS pulls this pin LOW (or the daemon signals a halt).

6. Visual Diagnostics (LED Indicators)

LED	Color	Status / Meaning
External Power	**Green**	Primary 5V power source detected.
Full	Green	Battery fully charged (>3.9V).
Min	Green	Sufficient energy for a safe boot-shutdown cycle.
Safe	Yellow	Sufficient energy for a safe shutdown cycle.
Low	Red	**Critical level.** Immediate shutdown required.

7. Intelligent Power Management (IPM)

- **Safe-Start Logic:** Prevents "brown-out" loops by ensuring the Pi only starts when the battery can support the peak current of the boot process.
- **Shutdown Guard:** Monitors the Pi's state and ensures power is only cut after the operating system has safely unmounted the filesystem.
- **Input Threshold Tuning:** Onboard potentiometer allows adjustment for voltage drops caused by long input cables.

8. Estimated Runtimes with Raspberry Pi Zero2 WH

HSC Capacity	No Load	100% Load
450F	46 min	13 min
850F	60 min	22 min
1100F	105 min	28 min

9. Software Support

- **qups-guard:** Native **open-source** daemon for automated monitoring and safe shutdown.
- **Compatibility:** Fully compatible with Raspberry Pi OS (Debian-based).
- **Repository:** github.com/aqexhu/qups-guard

HW Version: 1.0 | **Released:** 2025 **Manufacturer:** AQEX Electronics | aqex.eu